

Experience and progress with polychromatic EUV reflectometers and spectrophotometers.

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Introduction

Actinic spectral characterization of components like EUV-masks, EUV mask blanks, absorber layers, detector windows and spectral control filters is crucial for verifying production, process and under use performances.

E.g., high volume manufacturing (HVM) of EUV-masks requires high accuracy, precision and practicability of the actinic metrology, such that requirements for actinic reflectometry is targeted to <0.05 % in peak reflectance, and <0.002 nm in centroid wavelength (3 σ). Absolute accuracies should be of the same value (1 σ). This should be accomplished along with the reduced measuring spot size of down to <0.01 mm² as well as monitored alignment and positioning using fiducial mark.

With our proprietary polychromatic reflectometry, we have realized tools, which fulfill such demands together with fast measurements. Typically, for characterization of one small spot on a sample of << 0.1 mm² in size, exposure times – depending on spectral resolution - of 5 – 20 seconds are sufficient, which allow to characterize > 180 spots per hour or > 3 samples per hour with > 30 spots on each sample.

With the highest quality existing EUV-reflectometer developed for mask blank characterization (MBR), 2000 channels of 1.6 pm width are measured with 20 seconds exposure time and precision of 0.1 % in peak reflectivity and 0.005 nm for centroid wavelength are routinely achieved on both reflective multilayer coated and absorber coated blanks. It has been demonstrated that our EUV-lamp enables EUV-MBR operation without wear or components change for > 300 million pulses, which is > 100.000 full spectra measured at different sites or > 10.000 samples measured at 9 spots. In this work we are presenting our present status as well as the first steps to achieve the demanded target for HVM of EUV masks. We will analyze the factors and parameters which are critical to achieve this level quality.

With the flexible Spectrophotometer CEUVS exposure times of 5 seconds per spot with a LPP source are sufficient to characterize the spectral characteristics in normal and grazing incidence reflection or transmission of filters or gases with about 8 pm with of the > 2000 spectral channels.

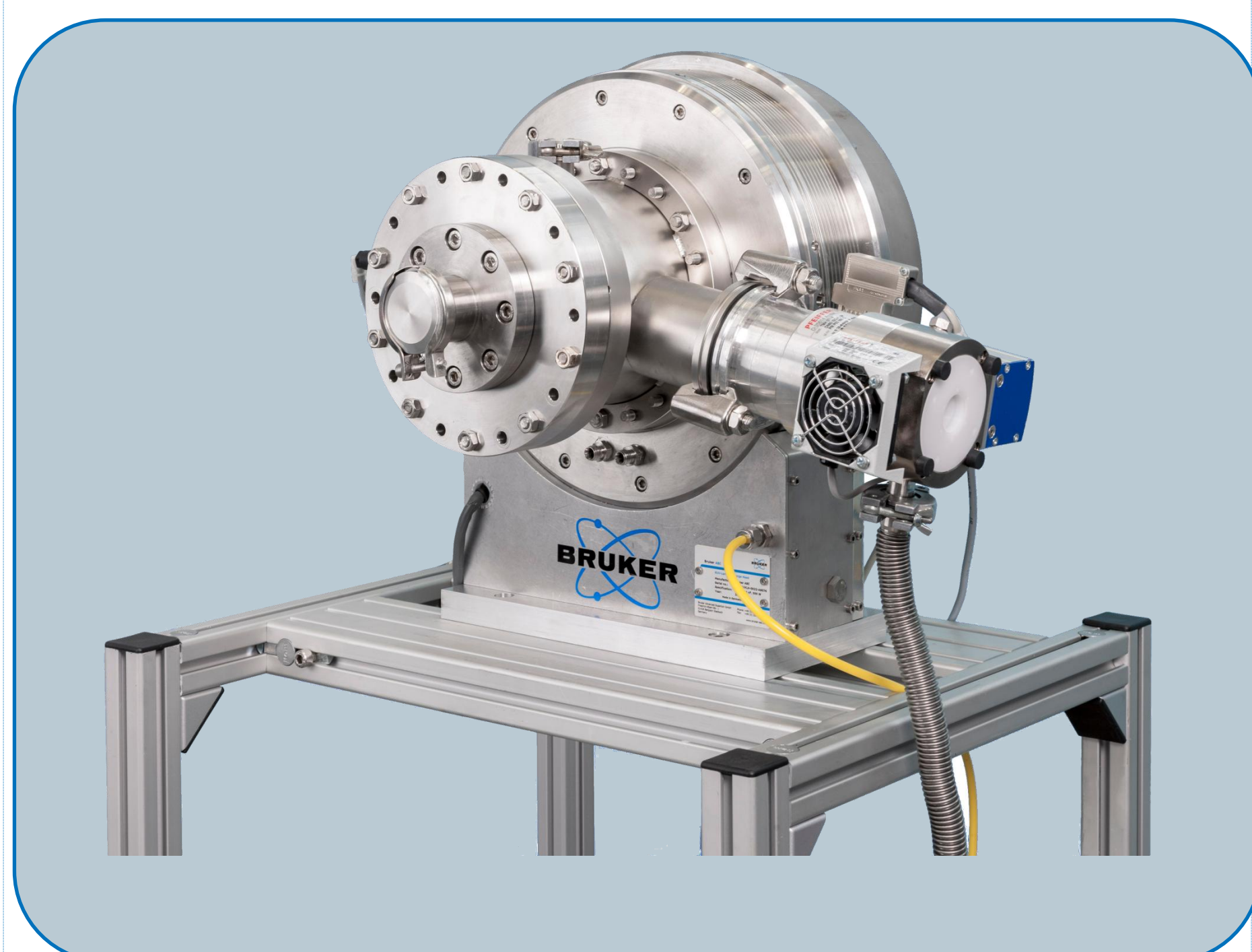
In-House Source selection

With our EUV and XUV sources, both types: discharge produced and laser produced, we have the option to select the best suited source for any application. Our own portfolio is supplemented by sources available at our research partners, e.g. Fraunhofer, Laserzentrum Hannover, Rhein-Ahr Campus Remagen, MBI.

In summary we can cover narrow and broadband emission spectra, power levels of up to 40 W of EUV-inband radiation, brightness exceeding 200 W/mm²/sr; source sizes from 20 μ m to 1 mm in diameter and lifetimes up to years.

But what is also of importance is that we can also apply the most economical solution for any given application; such as our EUV-Lamp, or a < 5 mW in 2 p sr EUV inband LPP source.

With our design experience in systems for synchrotron and in realizing stand alone tools in UHV, integration and mechanical and vacuum quality is straight forward.



EUV-Lamp head: one of our standard source work horses

EUV Mask Reflectometer

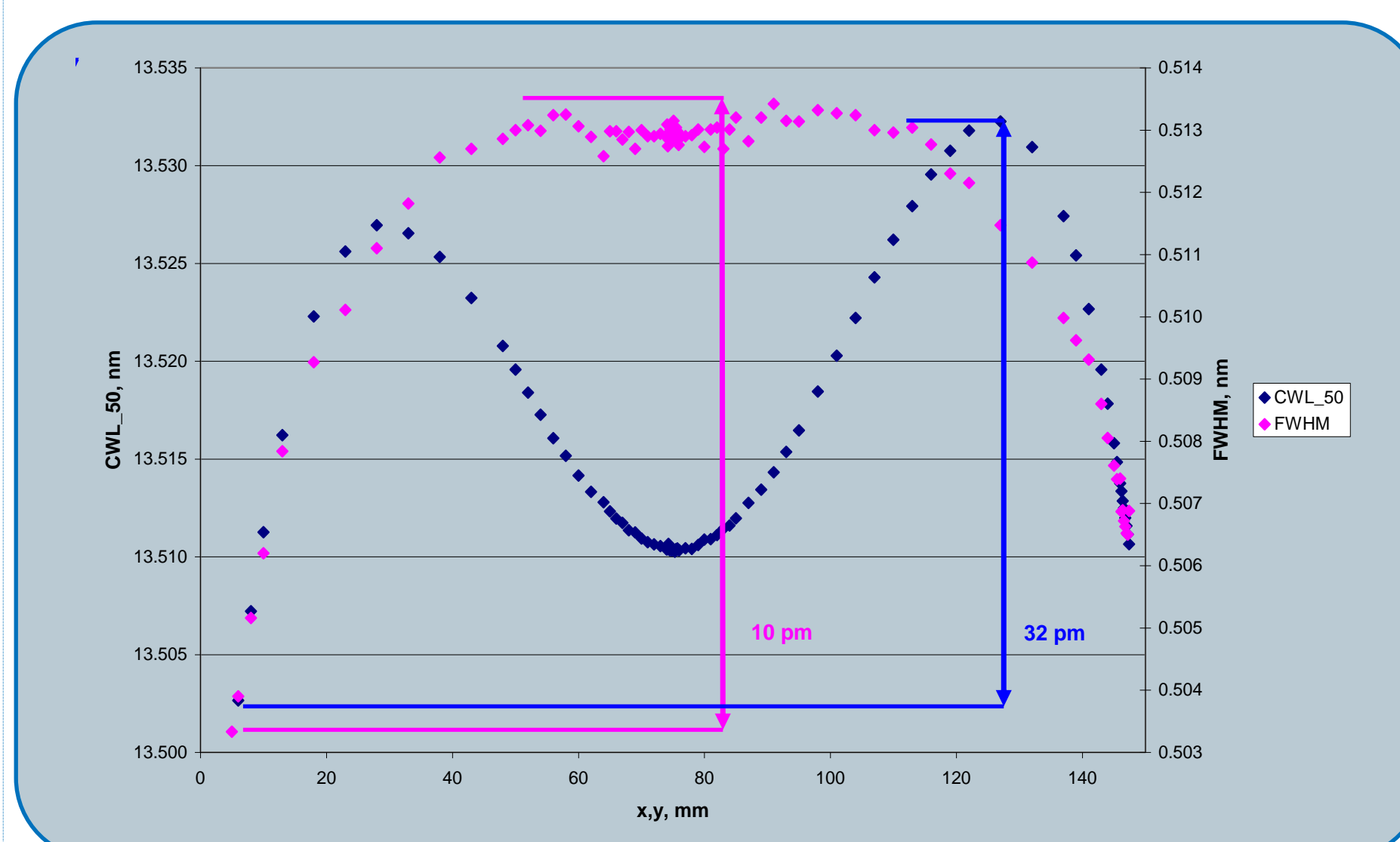


EUV Mask Reflectometer

The EUV-MBR meets the extreme demands from the semiconductor industry on EUV-mask metrology when ramping up EUV-Lithography. EUV-Lithography around 13.5 nm. In more general, the EUV-MBR is the most advanced tool of our portfolio in XUV (2-20 nm) metrological XUV-lab-solutions. The EUV-MBR is designed to achieve:

- Wavelength accuracy of better than 2 pm for CWL₅₀ and FWHM.
- Less than 20 seconds per spot
- Small Spot of < 500*100 μ m² * (< 100*100 μ m² feasible)
- 2000 spectral channels of 1.6 pm width.
- Accuracy on reflectivity: PV <0.5 % abs.
- Resolution limit on absorbers: < 0.1 %

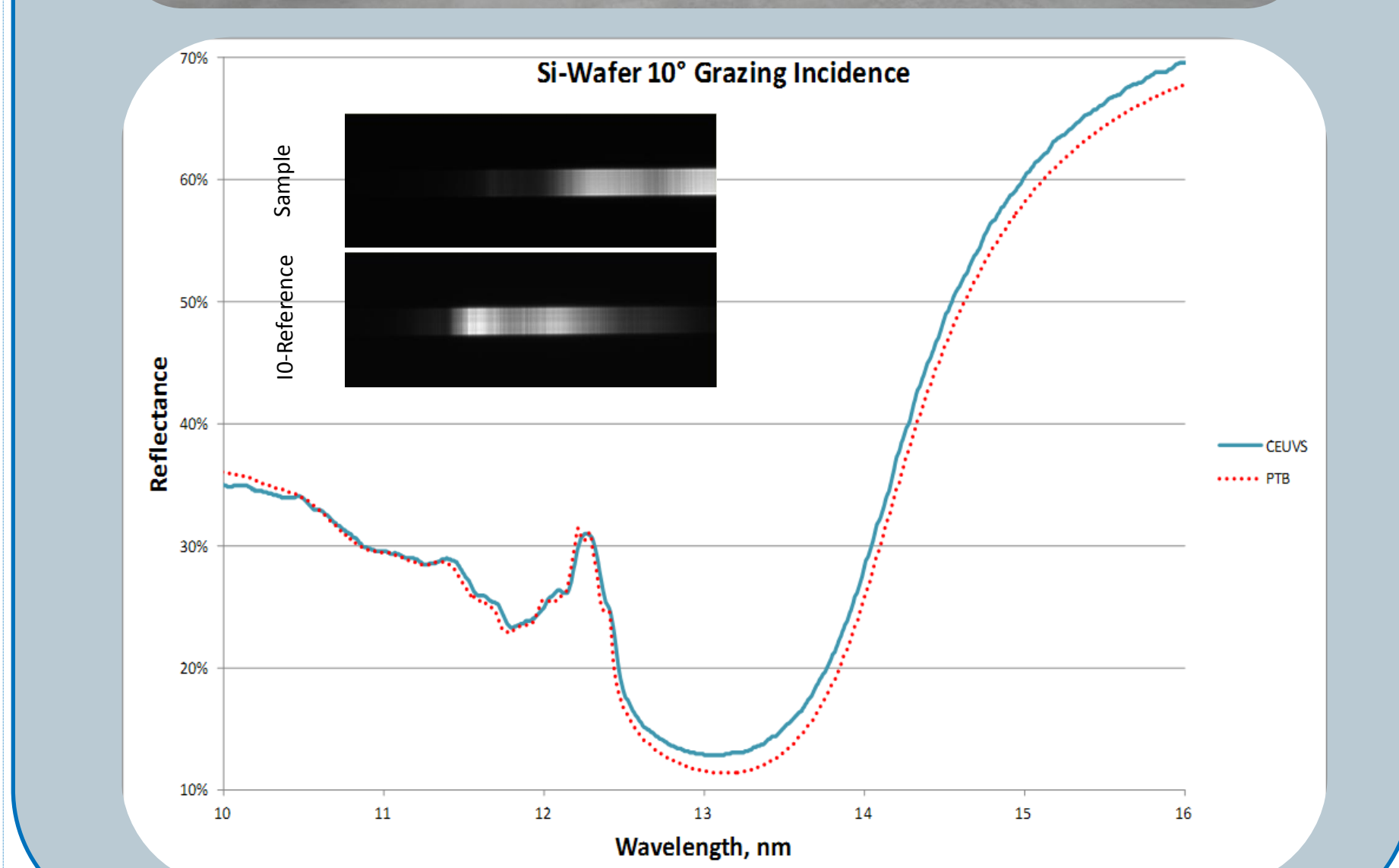
With a EUV-MBR in our own labs, we are continuously working on our own product upgrade for future solution and support of our customers. This EUV-MBR is available for demonstration and use for measurements to partners in collaborations and for third parties under special agreements.



Result of measuring mask blank homogeneity with EUV-MBR

XUV Spectrophotometer

The XUV / EUV Spectrophotometer is designed to offer high flexibility in samples and geometries (Transmission, normal or grazing incidence reflection). Fast data acquisition is achieved with our proprietary polychromatic concept.

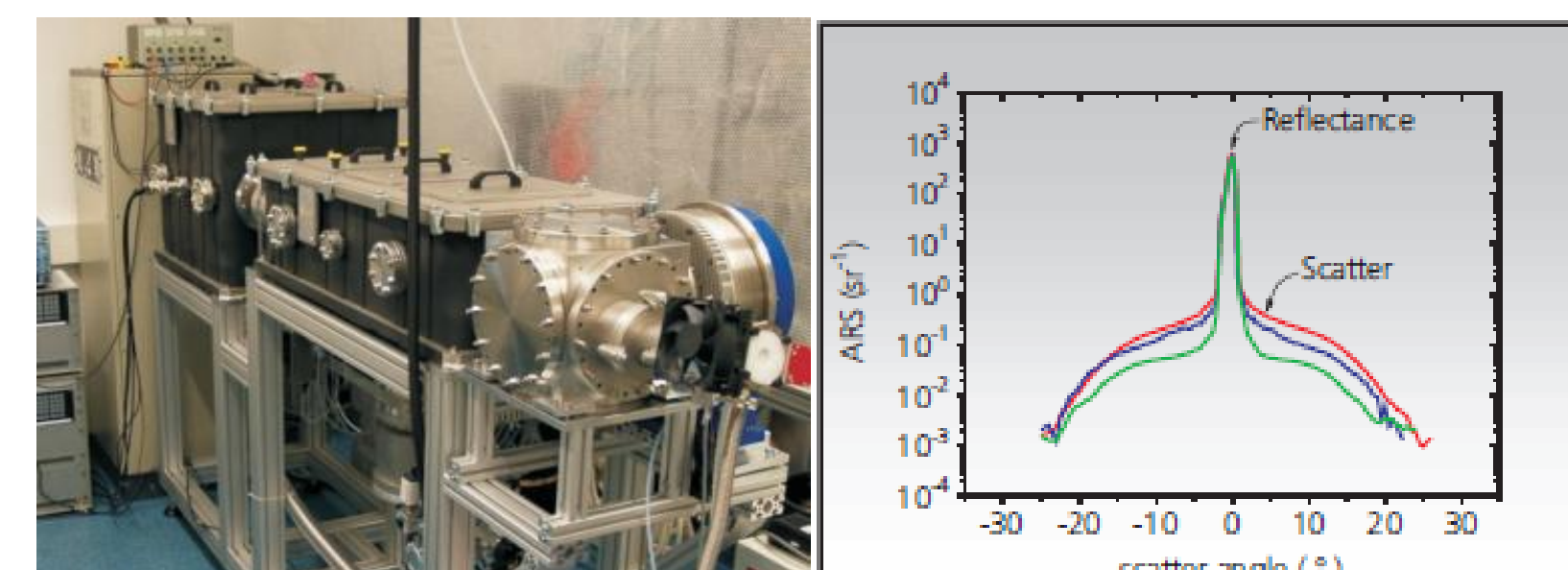


XUV / EUV Spectrophotometer and result on Silicon wafer grazing incidence reflection compared to measurement at PTB

Scatterometer and WAXUVS

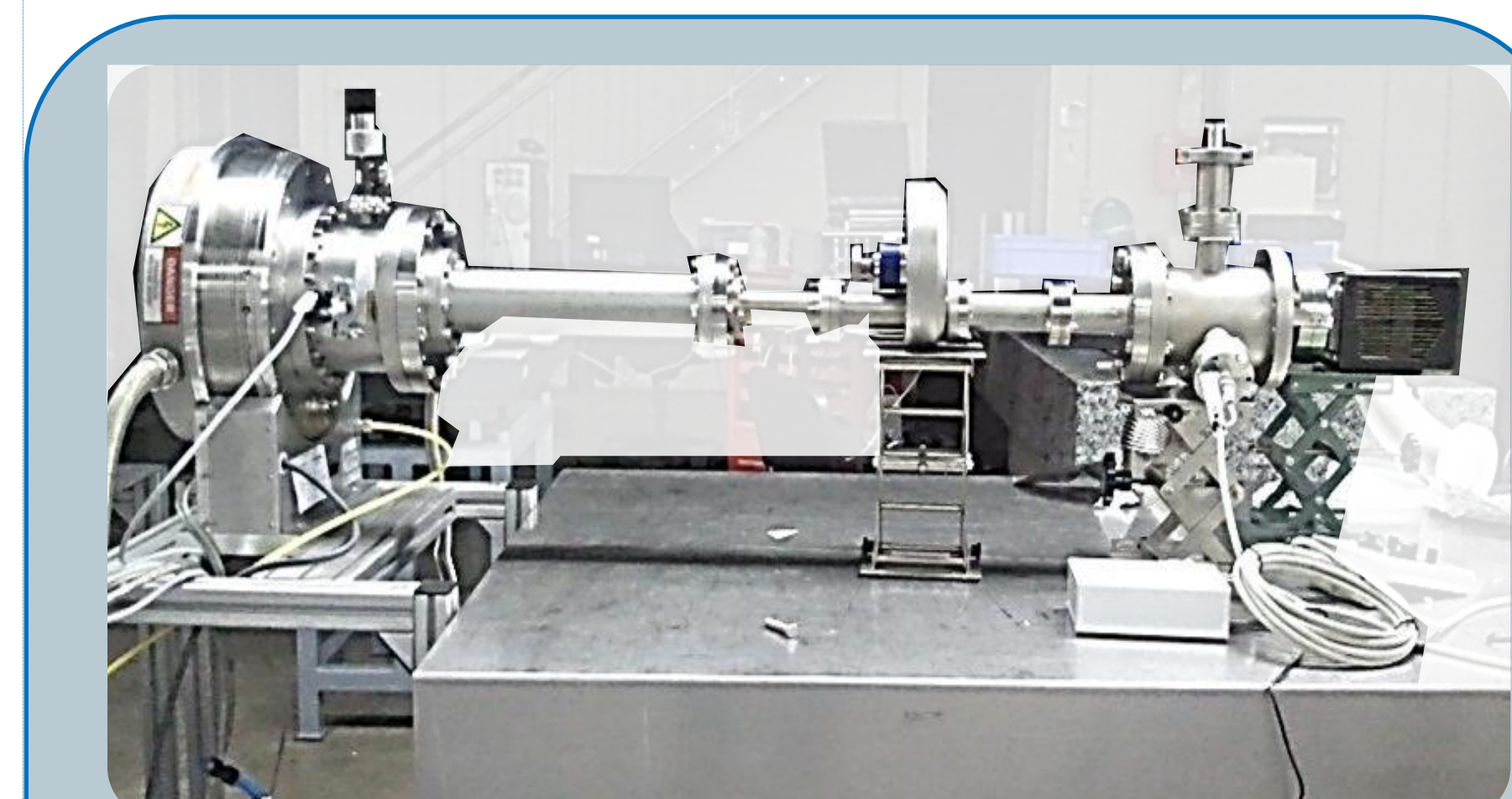
Scatterometry and Diffractometry, might thy be actinic EUV or monochromatic are straight forward with the available solutions.

Our partners at Fraunhofer IOF have realized an EUV inband scatterometer (MERLIN) based on the EUV emission of our EUV-Lamp.



Scatterometer MERLIN at Fraunhofer IOF with EUV-Lamp

In own experiments, we have demonstrated wide angle scattering with narrowband XUV emission from our EUV-Lamp in a proof of principle experiment,



Proof of feasibility experiment on wide angle scatterometry

Synchrotron based solutions

Besides our laboratory source based systems, we have even wider scope in supplying systems to synchrotron beamlines worldwide. One special example is the reflectometer supplied to the PTB in the past to be used to measure most of the EUV-samples fabricated in Europe.



View into Reflectometer chamber supplied by us to the PTB at BESSY.

Conclusions

We have demonstrated to provide integrated solutions of sources and metrology to a variety of tasks in the past based on our core competences, our own EUV sources and our design solutions. Experience of systems in the field allows us to continuously work on customer specific tailored tasks or supply our standard products

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